Int J Life Cycle Assess (2009) 14 (Suppl 1):S70–S79
DOI 10.1007/s11367-008-0057-1

Environmental evaluation of aluminium cans for beverages in the German context

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Received: 17 July 2008 / Accepted: 13 December 2008 / Published online: 21 February 2009

Abstract
Background In the years 2000 and 2002, the German Environment Agency in Berlin (UBA) published the results of a comprehensive LCA study on beverage containers comprising aluminium cans with volumes of 330 ml and 500 ml. Starting with the aluminium can scenarios and the respective results obtained during the UBA study, additional analyses were performed by IFEU in 2003, a German consultant having been a member of the project team working on the UBA study. The objective was to examine the influence of selected parameters on the LCA profile of carbonated soft drink containers. Data and method were in complete analogy with the LCI and LCA part of the UBA study.
Materials In 2006, the aluminium industry commissioned a study on further influential factors that help determine the sale of certain types of beer, studying the effects of two selected parameter settings on the comparative results of the aluminium can against the refillable glass bottle. In this scenario, special attention was given to two influential factors, the distribution distance—distinguished by regional and nationwide distribution—and trippage rate.
Results and discussion The results of the initial LCA from the years 2000 and 2002 showed, for the examined parameters container weight, rate of post-consumer recovery of used containers, degree of recycled content and quality of the recycling routes, that each had a considerable influence on the environmental impact profile of the aluminium can within the given framework. Can weight and recycling rate were sensitive factors in the impact categories of *climate change*, *fossil resources*, *summer smog (POCP)*, *acidification* and *terrestrial eutrophication*. Can volume affected virtually all impact categories examined.
Conclusions By now, individual improvement options have already been put into practice in Germany. The environmental profile of the average 330 ml aluminium can on the German market can be expected to be ahead of that of the aluminium can at the time of the UBA study. The introduction of a 500-ml can on the market denotes a fundamental step forward in improving LCA results of the aluminium can as a container for beverages.

Keywords Aluminium can · Beverage containers · Beverage distribution · Life cycle assessment · Post-consumer recovery · Refillable glass bottle

1 Background

In the past 15 years, a large number of life cycle assessments (LCA) of beverage containers have been carried out in Germany. During the same period of time, the Federal Ministry for the Environment (BMU) has been increasingly using LCA results as a major source for decision-making. This particularly regards the environmental evaluation of packaging systems as well as the achievements of recovery of used packaging waste in the context of the German Packaging Ordinance (PackOrd).

As such, environmental evaluations are carried out by the Federal Environment Agency (UBA), which provides technical consultancy to BMU. A methodological framework for life cycle impact assessment and interpretation had

Responsible editors: Gerald Rebitzer and Jörg Schäfer

Special Issue "Life Cycle Performance of Aluminium Applications"

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been developed by the UBA in 1999 (UBA 1999). This framework used a combination of scientific knowledge and political targets to set up a ranking scheme of environmental impact categories.

The 'UBA approach' also comprised further methodological conventions such as the choice of procedure for allocation in open-loop recycling. In addition, it required one-way beverage containers to be benchmarked against refillable containers.

The aluminium industry has intensively worked with the 'UBA approach' to better understand the environmental performance of aluminium beverage cans under German market conditions. A recent study focused its investigation on beer cans and their environmental competitiveness against the refillable glass bottle for selected cases.

2 The German Packaging Ordinance

The German Packaging Ordinance (PackOrd) first came into effect on June 12, 1991, under the German Waste Act. With this ordinance, Germany became the first country to set requirements for the recovery and recycling of sales packaging, i.e., post-consumer packaging, and as such this ordinance was the German government's answer to the increasing quantity of beverages filled and sold in one-way containers. This trend posed a threat to the national waste management situation, where it was noted that landfill capacities were decreasing as the volume of waste was increasing.

In its original version, the PackOrd already provided the foundation of today's deposit on one-way beverage containers in Germany. In order to reduce household waste, the PackOrd established two distinctive measures, imposing a minimum quota for refillable beverage containers and material-specific recovery targets.

The refillable quota had been set to 72%, which corresponded with the share of refillables in Germany in 1991. The quota was intended as an incentive for retailers and packaging producers to maintain the corresponding share of refillables, although, since 1997, this quota has no longer been met. As a consequence, a mandatory deposit came into effect in January 2003.

Meanwhile, BMU issued a revision of the PackOrd (second revision from the year 2002), a main feature of which was to substitute the quota for refillable beverage systems with a concept that involves so-called environmentally friendly packaging systems. Decisions as to which beverage containers were to be included in this category were taken up by the Ministry with reference to the results of Life Cycle Assessments, amongst other criteria.

This concept has since been applied throughout the following revisions. In the fourth revision, issued on July 19, 2007, the PackOrd addresses the following Waste Management Objectives in Article 1.

1. "The purpose of this ordinance is to avoid or reduce the environmental impacts of waste arising from packaging. Packaging waste shall in the first instance be avoided; reuse of packaging, recycling and other forms of recovery shall otherwise take priority over the disposal of packaging waste."
2. "This ordinance aims to increase the share of beverages filled into refillable drink packaging and ecologically advantageous one-way drink packaging to at least 80%. The Federal Government shall conduct the necessary surveys on the respective shares and shall publish the results annually in the Federal Gazette. The Federal Government shall assess the impact on waste management of the provisions contained in Articles 8 and 9 by no later than January 1, 2010. The Federal Government shall report its findings to both the Bundestag (Federal Parliament) and the Bundesrat (Federal Council)."

In addition, in article 3(4), the PackOrd defines that "ecologically advantageous one-way packaging within the meaning of this ordinance as:

- Drink carton packaging (brick packs, gable-top cartons),
- Drink packaging in the form of polyethylene bags,
- Stand-up bags."

Furthermore, annex I to Article 6 specifies the requirements for recovery of sales packaging, demanding that, "on average for the year, at least the following quantities of packaging in percent by weight must be consigned to recycling; [listed by material]: 75% glass, 70% tinplate, 60% aluminium, 70% paper and cardboard, 36% plastics (refers to mechanical recycling), and 60% composites" (Verpack 1998).

The LCA findings have essentially caused a fundamental switch in the PackOrd replacing the preference of 'refillables' and 'one-way packs' with a classification of 'ecologically favourable' and 'ecologically not favourable' packs. It should also be noted that the recycling targets exceed those of the European packaging and packaging waste directive. In Germany, metal beverage cans collected under the green dot system had collection rates of 80%. A corresponding, recycling infrastructure had been developed in parallel. For aluminium cans under a deposit scheme, it can be expected that collection rates are even higher.

3 LCA on packaging in Germany

In the year 2000, the German Environment Agency in Berlin (UBA) published the results of the first phase of a comprehensive LCA study on beverage containers (UBA 2000). The study covered as many as 27 different

packaging systems used in the bottling and retail of mineral waters, carbonated soft drinks, juices and wines. For the functional unit, a differentiation had been made between family packs with container volumes larger than 500 ml and portion packs with volumes up to 500 ml.

For this purpose, a comparison of the packaging systems has been grouped according to the type of beverage contained. The single aluminium can system analysed in the UBA study (UBA 2000) is a 330-ml container designed for carbonated soft drinks with a weight of 15.6 g per can; this includes the mass of the body (12.7 g) and the lid (2.9 g). It has further been assumed, based on data obtained from the German Aluminium Industry and beverage can producers, that the body of the aluminium can is composed of 90% recycled aluminium[1] and 10% primary aluminium, with the lid composed completely of primary aluminium. Thus, the can is made of 4.17 g primary aluminium (27%) and 11.43 g recycled aluminium (73%). The recycling rate of used aluminium cans has been set to 75%. The competitive packaging systems compared against the 330 ml aluminium can in the UBA study consist of a refillable glass bottle, a disposable glass bottle and a steel can, all having a volume of 330 ml (UBA 2000).

In the second phase of the UBA study (UBA 2002), a variant of the 330-ml aluminium can with a smaller body weight (can weight 12 g) and a variant produced from a diminished electricity demand of the primary smelter (UBA 2002) had been examined. This second phase also comprised the assessment of so-called ‘new’ beverage container system. It included a 500-ml aluminium can, which had been compared to a refillable glass bottle, and a steel can of the same volume. The label, ‘new’, refers to packaging systems which had been introduced into the market during phase 1 of the study (UBA 2000), which was expected to gain a considerable presence on the market in subsequent years.

The UBA study had been peer-reviewed according to ISO-standard 14040ff. While an array of impact categories had been examined, the categories *climate change* (UBA=very high ecological priority), *fossil resources* (UBA=high ecological priority), *summer smog (POCP)* (UBA=high ecological priority), *acidification* (UBA=high ecological priority), *terrestrial eutrophication* (UBA=high ecological priority), *aquatic eutrophication* (UBA=medium ecological priority), *land use* (UBA=medium ecological priority)—regarded separately for ‘*forest area*’ and ‘*sealed area*’—had been considered by UBA based on an evaluation scheme published in 1999 (UBA 1999). These categories are amongst those most often referred to in packaging related to LCAs (Arena et al. 2003; Danish Environmental Protection Agency 1998; Talve 2001).

The UBA method (UBA 1999) uses an ordinal ranking scheme (A to E), where ‘A’ stands for very high environmental relevance and ‘E’ for very low. The ranking criteria have been defined by ‘environmental vulnerability’ and ‘distance to target’ which have been combined with the results of a normalisation step. Those three aspects have been combined into an ecological priority classification per impact category.

The term ‘environmental vulnerability’ allows the different environmental impact and environmental quality targets to be related to each other. This is achieved by ranking the impact categories in accordance with the extent of their impact on the environment. The ‘distance to target’ expresses how far removed the status quo still is from the political targets.

The indicator results—the graphical depiction representative of the degree of environmental impact for each impact category—for the aluminium can analysed in the UBA study (UBA 1999) are shown in Fig. 1 (330-ml containers) and Fig. 2 (500-ml containers). They are compared against the results of the competitive packaging systems. The aluminium can’s comparative environmental contribution (highlighted by diagonal grey bars) varies significantly depending on the impact category considered.

The sectoral analysis reveals that the production of primary aluminium, the rolling of the aluminium sheet and the subsequent conversion for the production of the can body dominates the potential environmental loads in the impact categories *climate change*, *fossil resources*, *summer smog (POCP)*, *acidification* and *terrestrial eutrophication*. An important although significantly minor contribution to the environmental impact is due to the recycling and re-melting of recovered aluminium packaging waste, which has been used as a secondary raw material in the can. Examples of the dominance analysis used for the 330-ml can are shown in Fig. 3 for the impact categories *climate change*, *fossil resource* and *terrestrial eutrophication*.

Potential impacts in the categories *aquatic eutrophication* and *land use (forest area)* have been related almost exclusively due to the use of corrugated cardboard in secondary and tertiary packaging and to a smaller degree of water emissions arising from bottling. The data for these processes, however, are not represented in Fig. 3.

When considering both variants of the 330-ml aluminium can, it has been found that the ‘weight reduced can’ is quite a bit more effective than the ‘lower energy can’ regarding the overall improvement of LCA results. Thus, results from both phases of the UBA study (UBA 2000, 2002) clearly indicate that the reduction of material demand for primary packaging, in particular the consumption of

[1] This information was obtained through data collection by the German Aluminium Industry in order to determine the use of primary and secondary aluminium in sheet production

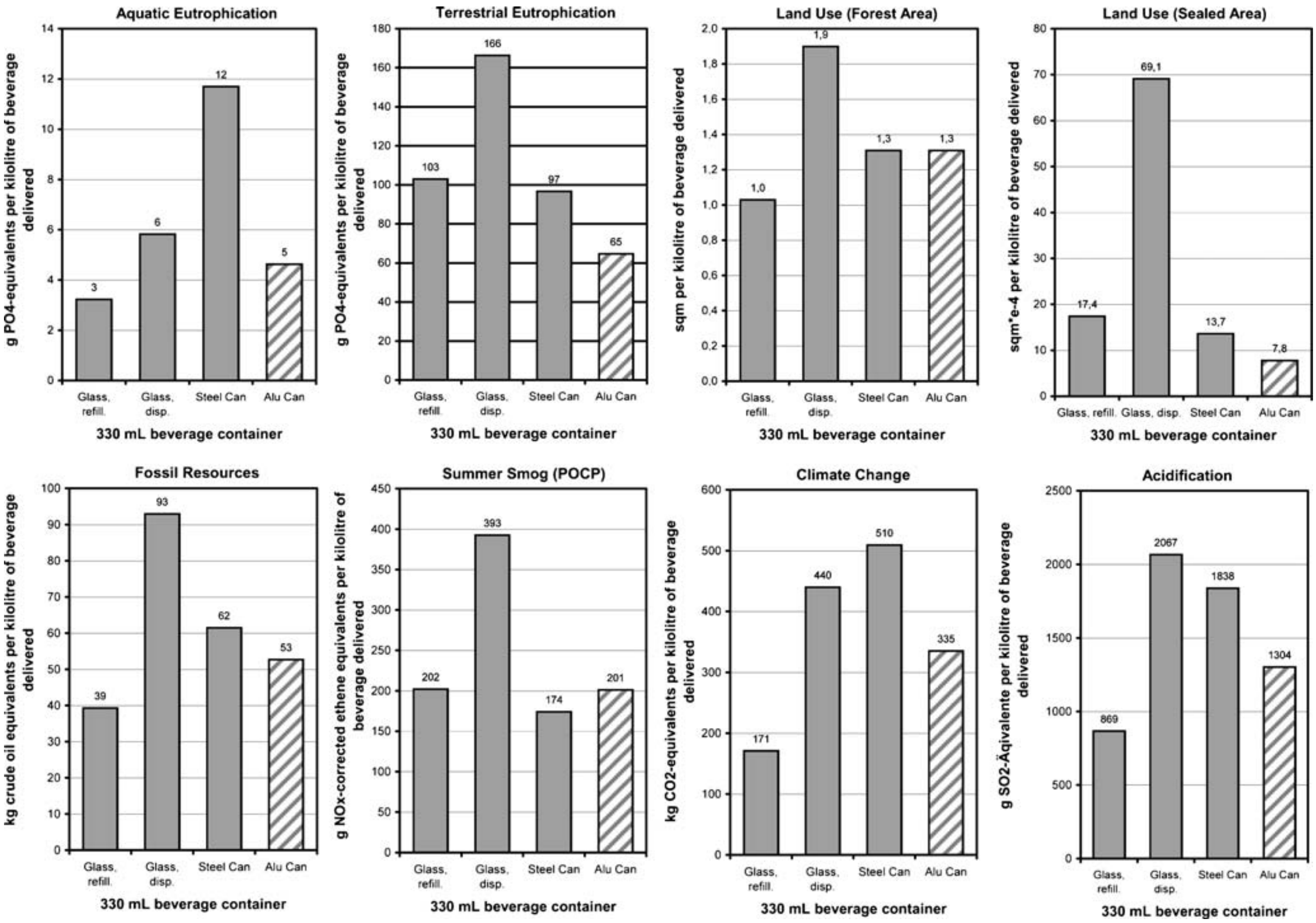

Fig. 1 Carbonated soft drinks in portion packs (330 ml). LCA results of UBA-LCA, phase 1

primary aluminium, together with a more efficient raw material processing and conversion, would be an important requirement for substantial improvements of the environmental impact profile of the aluminium can.

The aluminium-related processes and material flows in the can system are shown in Fig. 4. The flowchart also indicates how material flows are linked. Changes in recycling rates affect the amount of aluminium recovered for subsequent recycling into recycled aluminium. The amount of recycled aluminium available from this closed-loop system further determines the amount of primary aluminium required in body sheet production.

Based on the UBA-LCA (UBA 1999) study, BMU had concluded that the aluminium can was not considered an ecologically favourable beverage container. Consequently, since 2003, aluminium cans for beer and carbonated soft drinks have been sold with a returnable deposit in Germany.

On the other hand, the UBA-LCA (UBA 1999) also shows that the comparison of one-way packs with refillables may vary according to several parameter settings.

The resultant sensitivity parameters of one-way packs have been based on:

1. the weight of the container
2. the rate of post-consumer recovery of used containers
3. the degree of recycled content
4. the quality of the recycling routes (closed-loop recycling, open-loop recycling, downcycling)

Furthermore, the resultant sensitivity parameters of refillable packs are based on:

1. the ‘trippage rate’ (i.e., number of re-reuses of the refillable glass bottles)
2. the transport distance from filler to point-of-sale
3. the energy (and water) efficiency of bottle and crate cleaning

Stakeholders participating in the project panel of the UBA study (UBA 1999) have been offered access to the data pool and scenario models of the UBA study (UBA 1999) for additional assessments, in order to be able to

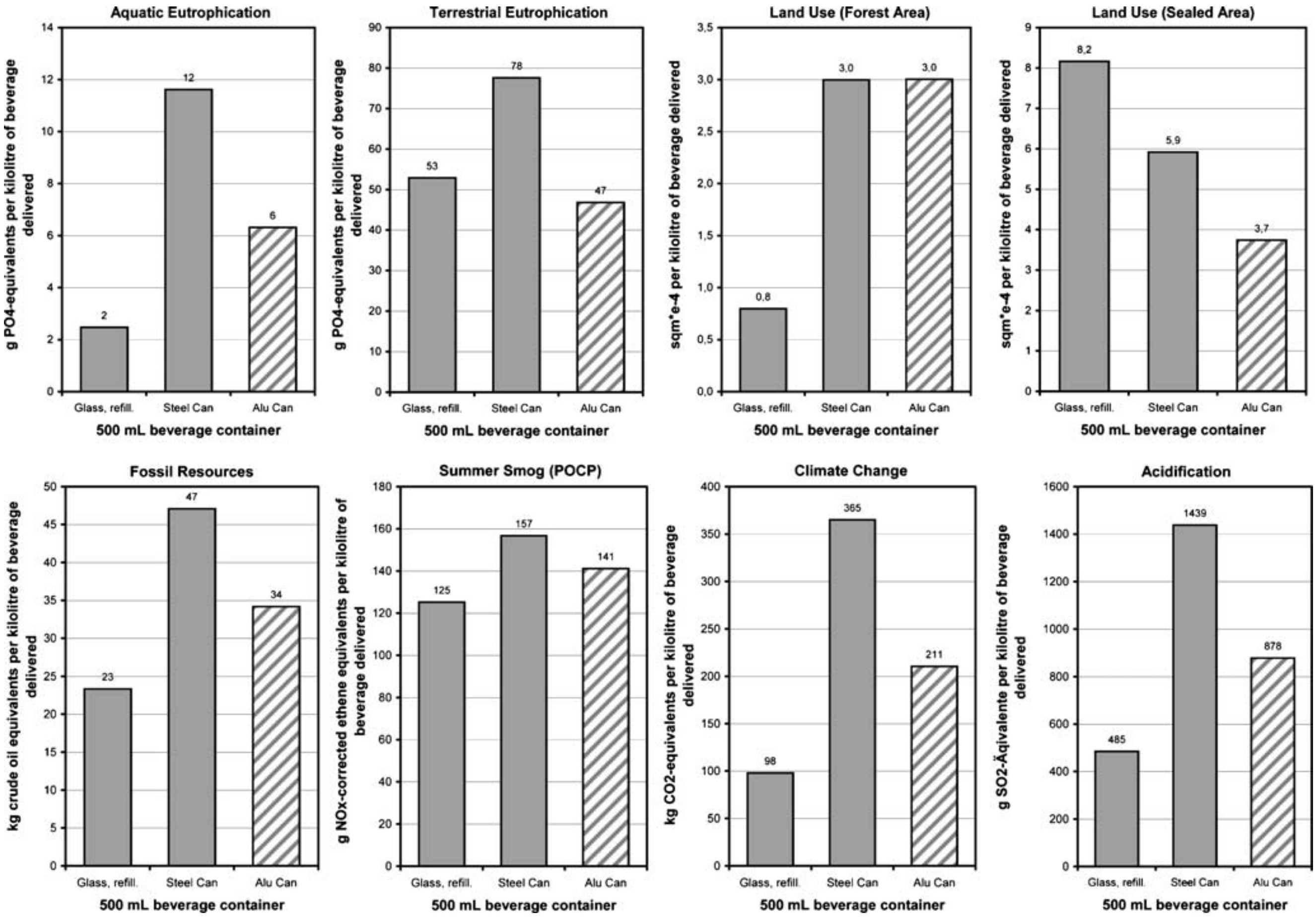

Fig. 2 Carbonated soft drinks in portion packs (500 ml). LCA results of UBA-LCA, phase 2

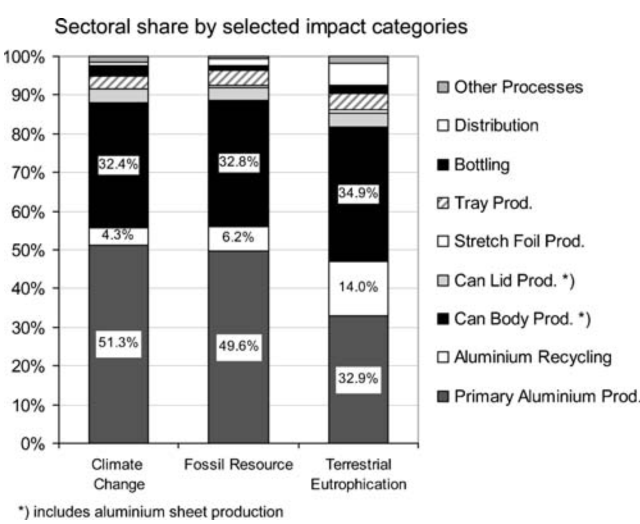

Fig. 3 Sectoral share of processes and life cycle steps in the packaging system of the aluminium can (330 ml). LCA results of UBA-LCA, phase 2

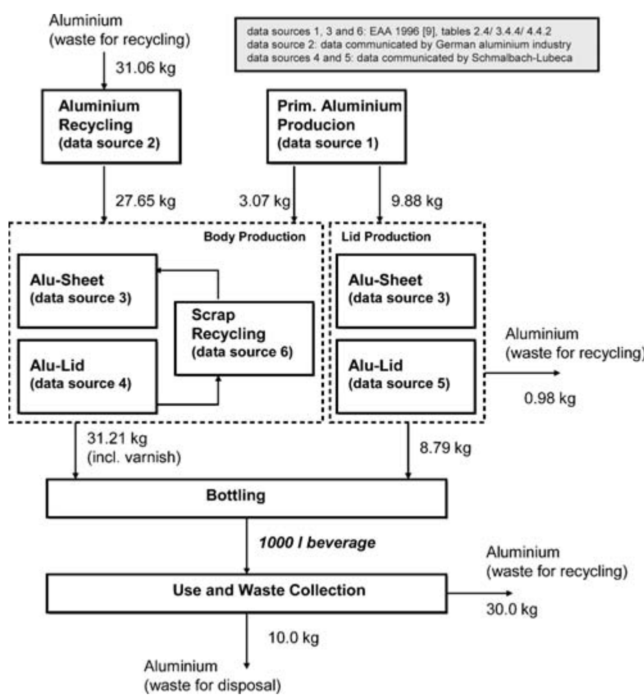

Fig. 4 Simplified aluminium mass flow in UBA scenario of aluminium can (330 ml)

address questions specific to individual industry branches. Based on these findings, the aluminium industry had commissioned a beer can exercise to examine the effect of selected parameter settings on the comparative results of the aluminium can against the refillable glass bottle.

4 The beer can exercise

The German beer market is under immense pressure to be innovative. The competition for market shares confronts beer companies with the need to cultivate their brand identity, to offer a new variety of beverages and to consider the form of packaging used, for instance through increasing individualisation of packaging, which has become an important factor for brand identification and customer loyalty. This shift has led to segmentation of the beer market, among other changes. This exercise seeks to estimate the extent to which this development has influenced the environmental impact of beer packaging.

As a first step, information had been gathered in order to gain an overview of the beer market. For this purpose, research had been conducted through inquiries to breweries and research institutes. Additionally, the expertise of 'Gesellschaft für Verpackungsmarktforschung'[2] (GVM 1997) had also been employed (Fig. 5). Special attention had been paid to the influential factors of 'distribution distance' and 'trippage rate'.

The findings indicated that it is sensible to categorise the beer market according to 'types of beer', namely standard beer types, special beers (for instance 'Kölsch'—beer from Cologne—or wheat beer) and trendy beer types. Moreover, it is important to differentiate beer according to standard containers, assortment-specific containers and individual containers. Bearing these three factors in mind, three case conditions have been selected for each of which the environmental impact profile of a 500-ml aluminium beverage can has been compared against a 500-ml refillable glass bottle. The cases have been defined for:

1. Regional (standard) beer in standard containers [assumption—trippage rate=25, distribution distance=100 km]
2. Nationwide distributed beer, such as those appearing in the case of successful trendy beers in assortment-specific containers [assumption—trippage rate=11, distribution distance=680 km]
3. Trendy beer in individual containers, which could not establish itself in the market for a long period [assumption—trippage rate=3, distribution distance=500 km]

[2] Gesellschaft für Verpackungsmarktforschung (Society for Packaging Market Research), Wiesbaden, Germany

The functional unit has been defined to be the type and amount of packaging required to pack and deliver 1,000 l of beer to the point-of-sale. All processes from raw material sourcing and processing to final disposal or recovery and recycling have been included. The calculations and assumptions made for this exercise have been performed on the basis of the UBA study (UBA 1999).

For the aluminium can, a total mass of 17.2 g including varnish has been assumed, of which 14.4 g are contained in the body and 2.8 g in the lid. For all calculated aluminium scenarios, a standardised corrugated board tray of a mass of 162 g has been considered.

For the comparison with the aluminium can, a 380-g amber bottle of grade type 'NRW bottle' has been considered with a recycled content of 65%. A crown cap of 2.2 g serves as the lid. The mass of the label has been set at 1.15 g. The bottles are transported in bulk in a HDPE refillable crate (20 bottles per crate, 1,850 g crate).

The aluminium industry (GDA 2001) has proposed two important framework conditions for the life cycle assessment:

(a) The application of a recycling rate of 95% for aluminium cans; and
(b) The application of the 100% allocation method for crediting of primary aluminium displaced by aluminium recovered from used beverage cans ('substitution method').

The recycling rate has been approximated, taking into consideration the aluminium industry's expected changes as a result of the implementation of a uniform nationwide deposit system starting in Germany in May 2006 with a relatively high deposit fee of € 0.25 per beverage can.

The 'substitution method' is the allocation approach for open-loop recycling favoured by the aluminium industry. The background of this approach is found in Atherton (2007) and EAA (2005a). Atherton (2007) in short states that: "

a. Metals are characterised by metallic bonding that provides distinct structures and properties. As this type of bonding is not affected by melting, metals can be recycled over and over;
b. Primary metal production therefore only fills in the gap between the availability of secondary material and total (market) demand;
c. The overall benefit of end-of-recycling therefore is the decisive factor that should be taken into account when determining the environmental impact of a metal product system."

The conclusion of the metal industry is that the recycled content approach is not useful for a life cycle based assessment of metal products. The European aluminium

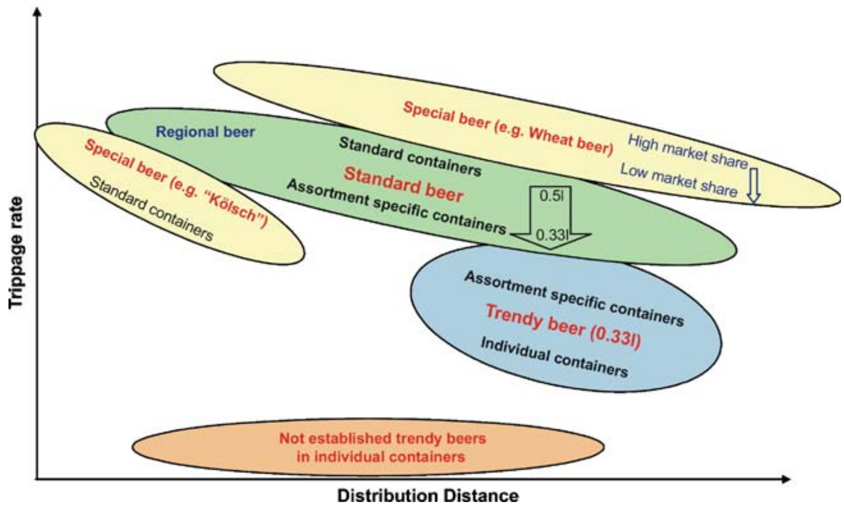

Fig. 5 Influence of the type of beer, type of beverage containers and distribution distance on the trippage rate. Source: GVM, Wiesbaden 2005; on behalf of the German Aluminium Packaging Recycling Ltd.

industry goes one step further by proposing the use of the so-called substitution method for LCA of metal products (EAA 2005b). It differentiates two cases: "

a. If the inherent properties of the aluminium material are not changed during recycling then the credit for displacement of virgin aluminium (in any aluminium product system) should be allocated with 100% credit, i.e. at a 1-to-1 mass ratio ('substitution method');
b. If, however, the inherent properties change, the allocation factor should then be adjusted according the market value of the recycled aluminium (so-called 'value-corrected substitution method')."

The underlying assumption of this approach of the metal industry is that only the availability of recycled metals determines the recycled content of a metal product. In other words, primary metals are only required because there is not enough recycled metal on the market, which is the case in a growing economy.

The strategic goal of the aluminium industry, which is the maximisation of the acquisition and recycling of used aluminium products, has been reflected appropriately by the 'substitution method'. However, the aluminium can in this approach has been viewed as an element of an overarching aluminium material flow rather than a distinct individual product system.

In the UBA-LCA (UBA 1999), only that amount of recycled aluminium is accountable with 100% crediting to the can system, which is recycled back to the can system (closed-loop recycling). The latter implies a recycled content approach. Recycled aluminium which goes into other product systems (open-loop recycling) has been calculated with a 50% allocation factor.

The 50/50 method is the standard approach for UBA-LCAs and has been used as a sensitivity analysis in the present exercise. Additional background information on this allocation approach can be found in the UBA study (UBA 1999). The 50/50 method has often been discussed in the context of open-loop recycling (see Klöpffer 1996; Kim et al. 1997). According to Klöpffer (2007), this rule is furthermore commonly accepted as a 'fair' split between two coupled systems.

5 Results

In this article, the results of distribution case 1 (regional beer) and 2 (nationwide beer) have been presented. Depending on the case conditions, the results can either favour the refillable glass bottle or aluminium can, respectively (Figs. 6 and 7). This can be seen in the impact category *climate change*, which receives special focus in the 'beer can exercise' due to the fact that this is an area that has gained a high degree of public and political attention in recent years, and as such is ranked by UBA as a very high ecological priority.

In the regional distribution case (see Fig. 6) for the refillable glass bottle, the indicator results of about 92 kg of CO_2 equivalents per 1,000 l of beer are attained. In contrast, environmental impact profile for the nationwide distribution (see Fig. 7) of the refillable glass bottles is approximately 184 kg of CO_2 equivalents per 1,000 l of beer. This greater environmental impact for the nationwide distribution is a result of the greater distribution distance for the beverage containers, a trend which is perpetuated in the other impact categories where it is noted that the refillable glass bottle always has a lower environmental impact in the regional distribution case than in the nationwide distribution case.

Similarly, in the distribution results for the aluminium can, where the aluminium can contributes approximately

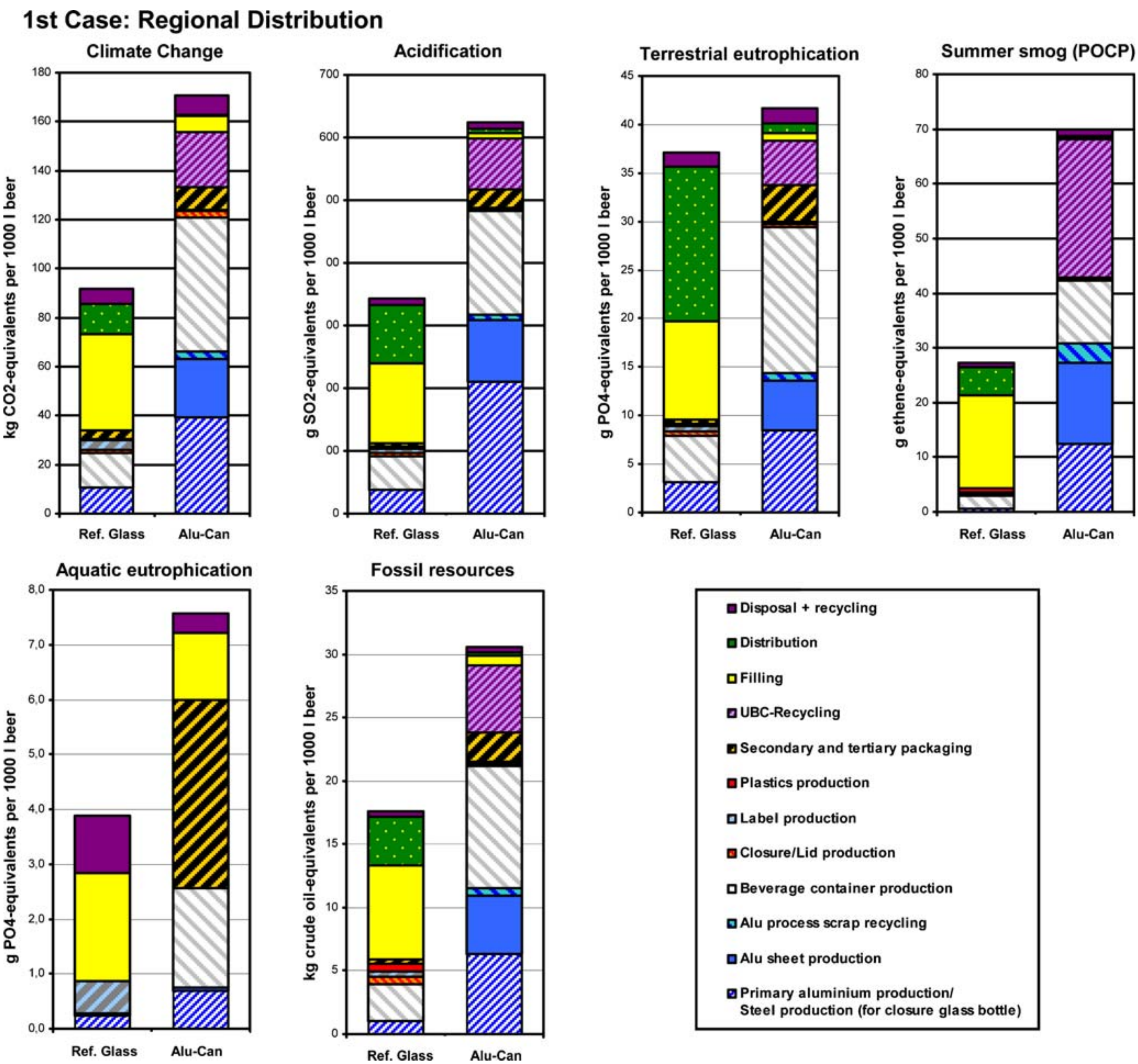

Fig. 6 Indicator results of case 1, regional distribution standard beer; distribution distance 100 km, recycling rate aluminium can 95%, trippage rate 25, 100% credit for recovered material

174 kg of CO_2 equivalents per 1,000 l in the nationwide distribution but only approximately 170 kg of CO_2 equivalents per 1,000 l in the regional distribution, again a result of the differences in distribution distance.

For the use of standard containers for regional beer like Kölsch[3] (assuming a transport distance of 100 km and a trippage rate for refillable bottles of 25, see Fig. 6), refillable glass bottles show a clear advantage because of the lower indicator results compared to aluminium cans.

In the case of a long transport distance, such as for the trendy beer types distributed nationwide ('Cross Germany Transport', here 680 km; see Fig. 7), the aluminium can tends to display slightly more positive results depending on the particular environmental impact considered. The change in the comparative results when switching from case 1 to case 2 is mainly influenced by the distribution distance chosen rather than the trippage rate of the refillable glass bottle, which has been set to 11.

The results also show for a regional distribution (see Fig. 6) that it is possible to achieve considerable smaller potential environmental impacts as compared to a nationwide distri-

[3] Very traditional old brewery in Germany with well-known brands

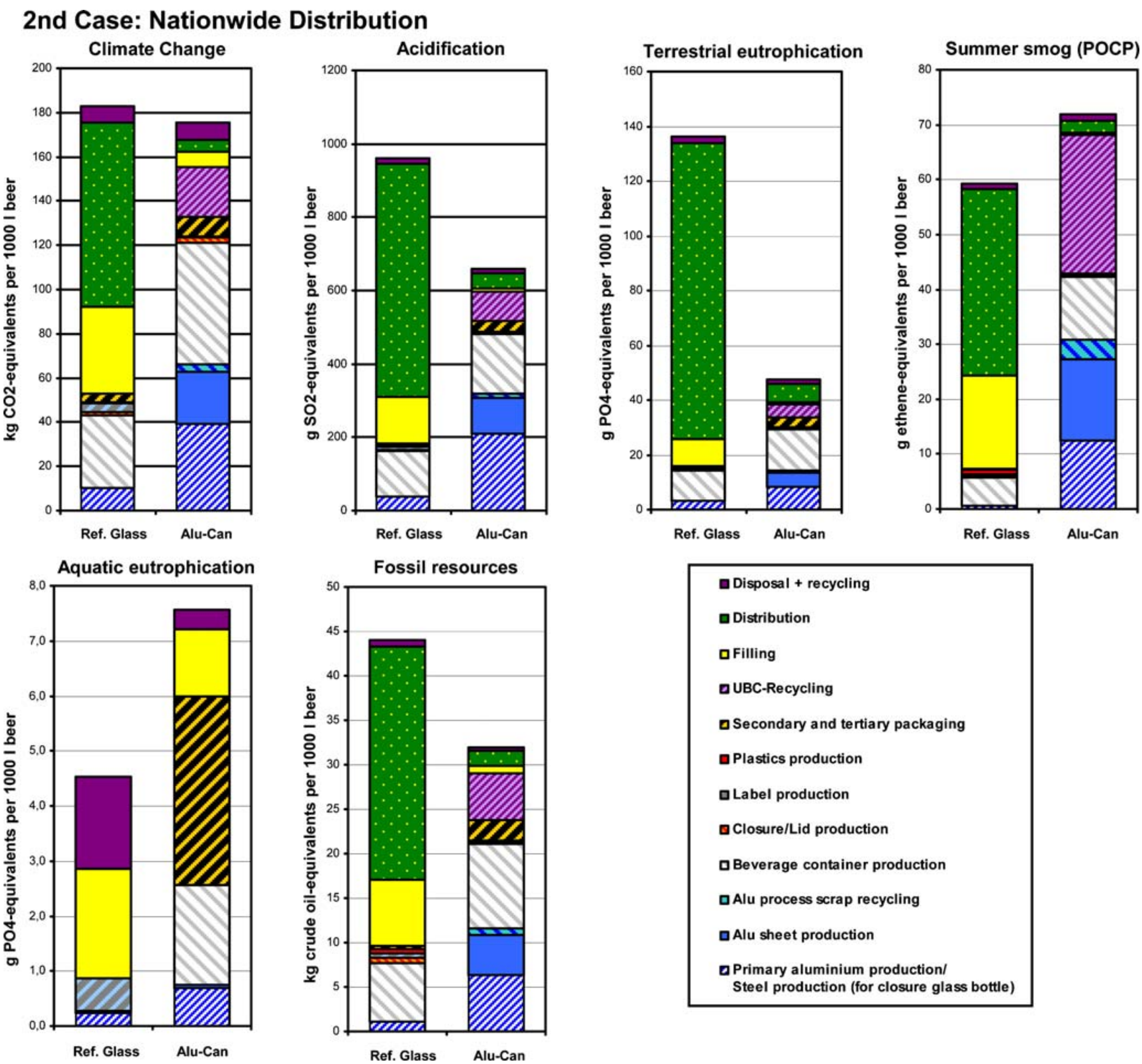

Fig. 7 Indicator results of case 2, nationwide distribution trendy beer; distribution distance 680 km, recycling rate aluminium can 95%, trippage rate 11, 100% credit for recovered material

bution (see Fig. 7) of beer to the points-of-sale. The refillable glass bottle's environmental impact profile increases by nearly 50% when a nationwide distribution is regarded.

The application of the substitution method in case 1 (see Fig. 6) shows positive results for the aluminium can. The results for the aluminium can are more favourable when a 100% allocation factor is used—depending on category, ranging between 11% for *summer smog (POCP)* and 21% for *acidification*—as compared to a 50% allocation factor (50:50 method). The latter has been used for sensitivity assessment in this study and is in accordance with the life cycle assessment method applied by UBA (1999). Nevertheless, the overall results have not been influenced as the refillable glass system is already favourable in the case of a 100% allocation factor.

In the case of trendy beer, the choice of the allocation factor leads to an inverse of the results for the impact category *climate change* in comparison to the aluminium can and a refillable glass bottle. For all other impact categories, the changes occur only in the extent of the differences, but not the ranking of impact category results between the systems.

6 Conclusions and perspectives

It should be noted that the cases for beer packaging 1 and 2 presented here reflect only a part of the overall German beer market. In reality, the ranges for both the trippage rate of refillable glass bottles and the distribution distances are much wider, with values stretching between greater and lesser than the ranges assumed in cases 1 and 2.

In Germany, the nationwide distribution trends of beer brands are very common. In the forefront are the brand names of large breweries, trend varieties such as ‘Gold’ beer or specialty beer. At the same time, however, the GVM has reported that the share of regionally distributed beer varieties have grown as well.

Besides the many breweries with a very regional focus (approximately one-half of German breweries are located in the state of Bavaria), there also exist nationwide breweries with a concentration on regional beer sales, e.g., ‘Veltins’. These breweries distribute approximately 70% of their sale quantity (draught and bottle beer) in a region encompassing up to 100 km.

Given this situation, it is worthwhile to analyse what the environmental advantages or disadvantages of regional in contrast to nationwide beer supply are, and in this respect what the role of the aluminium can is. The question has been addressed from the perspective of the brewer as well as that of the consumer. As the impact category *climate change* receives the highest ecological priority, it is used as an example to further expound this analysis.

The refillable glass bottle shows a high sensitivity in distribution distance for its environmental impact profile, whereas the aluminium can’s response to changing distribution distance is relatively small. This can be attributed to the greater transport efficiency of the aluminium cans which, due to their light weight, allow more beverage containers to be packed on a lorry per trip as compared to the rather heavy refillable glass bottle, which leads to a smaller amount of beverage containers being packed on a lorry per trip.

Overall, the conclusion is that the advice of ‘buy regional’ which is gaining popularity within sustainability concepts applies well in the case of ‘bottled’ beer. In such a local supply strategy, the refillable glass bottle plays a relevant role for minimising environmental impacts, particularly *climate change*. This should be taken into consideration by both the brewers, when offering their brands on the market, and the consumer, when making purchase decisions.

However, it cannot be neglected that consumer preference is often dependent on a variety of other factors and that many beer drinkers feel bound to certain brands regardless of the location of the related brewery. Thus, should a nationwide distributed beer brand be the consumer’s choice, the aluminium can may well be considered a packaging solution with environmental benefits. The precondition is that the cans are effectively recovered and recycled after use (recovery rates above 90% should be targeted).

It is crucial to remember that this study only assesses the environmental impact of beverage packaging. This study does not assess the overall environmental impact of logistics as such and therefore the findings of this article should not be used for drawing conclusions on the individual logistics structures of dedicated brewers.

Acknowledgement IFEU was one of the project partners working on the UBA study. The paper presented here is based on further scientific analyses of the UBA study and was performed by IFEU upon request of the German Aluminium Association.

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